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(19) (CA) **CANADIAN PATENT** (12)

(54) HYBRID UNSTABLE RESONATOR LASER CARTRIDGE

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Canada

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TI - Hybrid unstable resonator laser cartridge - has passive Q-switch bonded between lasing rod end and convex mirror

AB - CA1164990 Cartridge comprises a lasing rod with a partially reflective flat output mirror at one end and a fully reflecting convex mirror at the other. A passive Q-switch as an optical grade plastics member impregnated with saturable dye is between the rod and convex mirror, and an optical collimator adjacent to the output mirror.

- The rod, mirrors, switch and collimator are bonded together colinearly by optical grade adhesive to form an integrated structure. The output mirror is pref. a mirrored surface of the rod and the convex mirror is one surface of a resonator bonded to the switch. The rod is pref. Nd-YAG and the switch is of polymethylmethacrylate impregnated with a saturable absorber, organic dye or Ni-complex dye. The resonator is pref. plano-convex and the collimator is a plano-convex lens bonded and index matched to the output mirror. The laser has improved reliability when operating in extreme environmental conditions. (0/1)

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PR - US820340574 820118

PA - (USSA ) US SEC OF ARMY

IN - SAFYURTLU A C; WISNIEFF R E

MC - A12-E11 A12-L A12-T03 L03-F02

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DC - A85 L03 S02 V08 W06

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AP - CA820407781 820721

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TI - Hybrid unstable resonator laser cartridge - has passive Q-switch bonded between lasing rod end and convex mirror

IW - HYBRID UNSTABLE RESONANCE LASER CARTRIDGE PASSIVE Q-SWITCH BOND LASER ROD END CONVEX MIRROR

IN - SAFYURTLU A C; WISNIEFF R E

PA - (USSA ) US SEC OF ARMY

PN - CA1164990 A 840403 DW8418 011pp

ORD - 1984-04-03

IC - H01S3/11

FS - CPI;EPI

DC - A85 L03 S02 V08 W06

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The present invention relates to laser devices and more particularly to a Q-switched laser in integral cartridge form.

There are two types of lasers, namely those that operate to produce an output continuously, and those that are operated to produce a pulsed output. This invention is directed to the latter type. In pulsed output lasers, it is desired to intermittently produce a single relatively high amplitude pulse of coherent radiation. It has been found, however, that many lasing materials, such as Nd:YAG ruby crystals, employed in pulsed output lasers, tend to produce a series of low amplitude



pulses rather than the desired single high amplitude output pulse. The reason for this is that the lasing material begins to produce a coherent beam of radiation by stimulated emission before the inverted population density of the atoms of the lasing material has time to reach a very high magnitude.

10 In order to prevent a coherent beam of radiation from being produced in a pulsed output laser until sufficient time has elapsed for the inverted population density of the atoms of the lasing material to reach a very high value so that the desired single high amplitude pulse of coherent radiation is generated rather than an undesired series of low amplitude pulses, it has been the practice to insert a Q-switch between one of the reflective surfaces and the lasing material. The Q-switch in a first operating state lowers the effective gain of the laser to a point below unity so that the above described regenerative chain reaction does not take place. Therefore, by maintaining the Q-switch in its first condition for a time interval sufficient for the inverted population density to reach a high value and then switching the Q-switch to a second operative condition  
20 which effectively disconnects the Q-switch and permits the gain of the laser to rise above unity, the above described regenerative chain takes place and a single high amplitude pulse of coherent radiation is produced.

One well known type of Q-switch is a saturable absorber which operates as an optical absorption filter at the lasing frequency only when unsaturated, more particularly, a saturable absorber may be composed of a liquid or solid solution of an organic dye or may be gaseous in form. In any event, the saturable absorber when unsaturated absorbs a sufficient number of  
30 photons to maintain the gain of the laser below unity. However, the active absorbing photons causes the saturable absorber to ultimately become saturated at which time the optical absorption

filter becomes relatively transparent, permitting the gain of the laser to rise to a point above unity and a single pulse of coherent radiation of the predetermined frequency of the laser is produced.

U.S. Patent No. 3,500,234, entitled, "Unitary Q-switch Laser Device", P.V. Goedertier, which issued on March 10, 1970, discloses a unitary Q-switch laser device wherein the entire laser structure with the exception of the pumping source is made in the form of a single unitary structure having only one interface  
10 between materials of different indexes of refraction. The device furthermore includes a rod having one end polished to provide a spherical mirror surface forming one end of the resonator, a saturable absorber cell fixedly attached to one end at the other end of the rod, and a flat mirror surface fixedly attached to the other end of the saturable absorber which cooperates with the spherical mirror surface to form an elliptical cavity therebetween.

It is an object of the present invention, therefore, to provide an improvement in Q-switched laser devices.

It is another object of the present invention to provide  
20 an improved Q-switched laser cartridge in the form of a unitary integrated structure.

It is yet another object of the present invention to provide an improved Q-switched laser cartridge having an improved efficiency in reliability while operating in extreme environmental conditions.

#### Summary

Briefly, these and other objects are accomplished by a small size, light weight and low cost Q-switched laser in  
integral cartridge form for battery powered pocket size portable  
30 applications. More particularly, the laser cartridge of the

subject invention comprises a laser crystal, a passive Q-switch formed of an optical grade plastic, namely polymethylmethacrylate impregnated with a saturable absorber dye, a first reflector fixedly connected to the passive Q-switch material with optical quality adhesive, a second reflector fixedly attached to the other end of the laser crystal wherein the first reflector and the second reflector cooperate to form an unstable resonator, and collimating optics fixedly attached to the second reflector with optical quality adhesive wherein the laser crystal, the passive Q-switch and the first and second reflectors as well as the collimating optics form an integral assembly.

#### Brief Description of the Drawing

Figure 1 is a diagrammatic view of the preferred embodiment of the invention.

#### Description of the Preferred Embodiment

As shown in the drawing, reference numeral 10 designates a hybrid unstable resonator laser cartridge according to the subject invention which is adapted to be located in an optical pump cavity, not shown, utilized, for example, in battery powered pocket-sized portable military laser applications, a typical example of which is in a miniature rangefinder.

Accordingly, the device 10 is of a relatively small size, e.g. 3 millimeters (mm) by 20 millimeters. It is light in weight and is adapted to withstand a wide range of temperature and shock parameters ordinarily found in military environments. The cartridge 10 comprises an integrated structure which eliminates the need for an optical bench to align the resonator as well as eliminates the need to hermetically seal the device. The laser cartridge according to the subject invention is relatively simple in design and comprises a laser gain medium 12 in the form of an elongated Nd:YAG crystal rod having a partially reflective output

surface 14 which acts as a flat resonator element and which operates in conjunction with a convex resonator element 16 having a reflective surface 18 to form a hybrid unstable resonator configuration. Intermediate the convex reflecting surface 18 and the rod 12 is located a passive Q-switch 20 consisting of a saturable dye impregnated optical grade plastic, preferably being nickel-complex dyed polymethylmethacrylate (PMMA) whose optical density is selectively controlled. At the opposite end of the laser rod adjacent the partially reflective surface 14 is located an optical collimating lens 22. The four components 12, 16, 20 and 22 are bonded together in axial alignment by an optical grade adhesive forming an integrated structure. The adhesive interfaces are shown by reference numerals 24, 26 and 28. The adhesive used provides the necessary dimensional stability and strength which permits the joining and index matching of markedly different temperature coefficient materials, thereby permitting expansion and contraction without bond failure.

The plastic Q-switch 20 operates in a well known manner to saturate and decrease the threshold which increases the Q of the cavity when a predetermined inversion has been reached, thus allowing the formation of a laser output pulse which exits the collimating lens 22. While the Q-switch 20 can be molded in a variety of physical shapes and optical densities, it is shown for purposes of illustration as a substantially flat component. This type of Q-switch can be operated without complex driving electronics and thus allows the overall equipment to meet low costs, small size and weight constraints in a minirangefinder application, particularly adapted for military use.

The resonator configuration of the subject invention as shown is a novel version of a conventional stable resonator;



however, the output beam is transmission coupled instead of the conventional annular coupling. The output beam in turn is collimated with a simple plano-convex lens bonded and index matched to the partially transmissive output reflector. The unstable resonator substantially improves the beam quality of the output beam over the multi-mode stable resonator and approaches the diffraction limit. The efficiency is also increased by making use of the available mode volume. This is a direct result of the much more uniform intensity distribution within the unstable resonator allowing the passive Q-switch to bleach to the limits of the crystal rod diameter.

Another important advantage of the resonator configuration resulting from the structure shown is the elimination of hot spots which tend to cause damage of the passive Q-switch and the adhesive by excessive concentration of energy. The resulting effect is insurance of longer life and much improved reliability.

The laser cartridge of the subject invention is assembled by first bonding the convex mirror 16 to the plastic Q-switch 20. The laser rod 12 is next held in place and the mirror/Q-switch sub-assembly is aligned to form the resonator and bonded into place. Finally, the collimating lens 22 is bonded to the output surface of the crystal to yield the integral hybrid unstable resonator laser cartridge 10. Such a structure combines the desirable features of the large volume single mode operation and small angular divergence of the unstable resonator with the circular output beam and the more favorable far field energy distribution of the single mode stable resonator. The reliability is maximized by using a plastic Q-switch which together with the resonator and the collimating optics is bonded to the laser crystal to form an

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integral assembly less than  $0.14\text{cm}^3$  in volume.

Having thus shown and described what is at present considered to be the preferred embodiment of the invention, the same has been made by way of illustration and not limitation and accordingly all alterations, modifications and changes coming within the spirit of the appended claims are herein meant to be included.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE  
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A hybrid unstable resonator laser cartridge comprising in combination:

a laser medium in the form of an elongated rod type member;

partially reflective flat output mirror means located at one end of said rod type member;

fully reflective convex mirror means located at the opposite end of said rod type member, said partially reflective output mirror means and said fully reflective convex mirror means cooperating to form an unstable resonator;

passive Q-switch means in the form of an optical grade plastic member impregnated with a saturable dye, located between said rod type member and said fully reflective convex mirror means; and

optical collimator means adjacent said partially reflective output mirror means;

said rod type member, both said mirror means, said passive Q-switch means and said optical collimating means being bonded together in colinear relationship by optical grade adhesive means to provide a composite integrated structure.

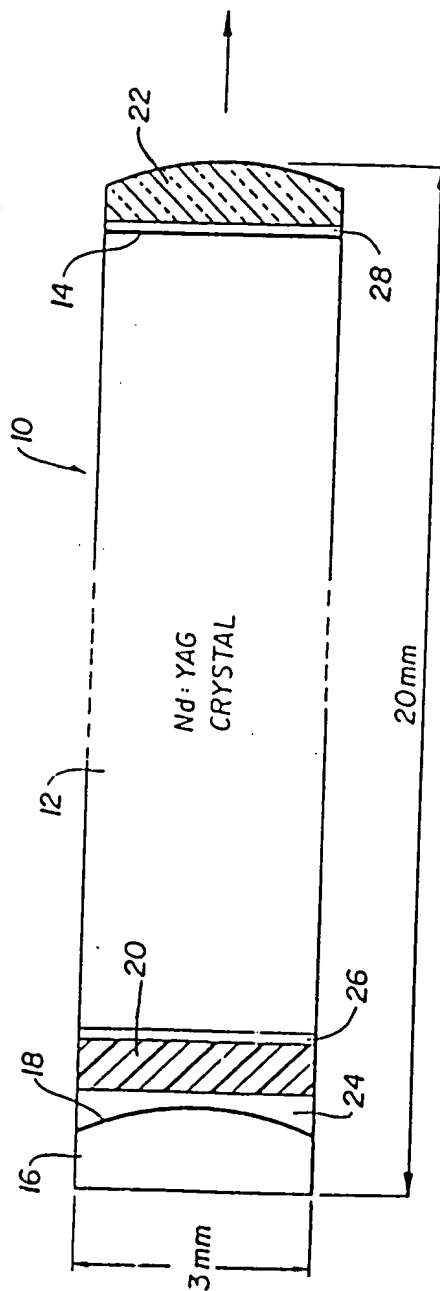
2. The laser cartridge as defined by claim 1 wherein said partially reflective flat output mirror means comprises a mirrored surface of said rod type member.

3. The laser cartridge as defined by claim 1 wherein said fully reflective convex mirror means comprises one surface of a resonator member bonded to said passive Q-switch means.

4. The laser cartridge as defined by claim 3 wherein said resonator member comprises a plano-convex member.
5. The laser cartridge as defined by claim 1 wherein said optical collimator means comprises a plano-convex lens bonded and index matched to the partially reflective output mirror means.
6. The laser cartridge as defined by claim 1 wherein the plastic passive Q-switch means comprises a material selected from the group of materials including polymethylmethacrylate.
7. The laser cartridge as defined by claim 1 wherein said optical grade plastic forming said Q-switch means comprises polymethylmethacrylate plastic impregnated with a saturable absorber.
8. The laser cartridge as defined by claim 1 wherein said passive Q-switch means comprises polymethylmethacrylate impregnated with an organic dye.
9. The laser cartridge as defined by claim 1 wherein said passive Q-switch means comprises nickel-complex dyed polymethylmethacrylate.
10. The laser cartridge as defined by claim 9 and wherein said laser medium comprises a Nd:YAG laser rod.



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